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**EXPLORATORY STUDY OF THE METAL BONDING OF
CORDIERITE AND STUPALITH**

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**THE OHIO STATE UNIVERSITY
RESEARCH FOUNDATION**

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WRIGHT AIR DEVELOPMENT CENTER

Statement A
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CORDIERITE AND STUPALITH**

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*The Ohio State University
Research Foundation*

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*Power Plant Laboratory
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**Wright Air Development Center
Air Research and Development Command
United States Air Force
Wright-Patterson Air Force Base, Ohio**

FOREWORD

This report No. 70 for Ohio State University Research Foundation, Project No. 488, was prepared under USAF Contract No. 33(616)-3. The contract was initiated under the research and development project identified by Expenditure Order No. R-506-67-C; it was administered under the direction of the Power Plant Laboratory, Aeronautics Division, Wright Air Development Center, with Mr. Bob L. Paris acting as the project engineer.

ABSTRACT

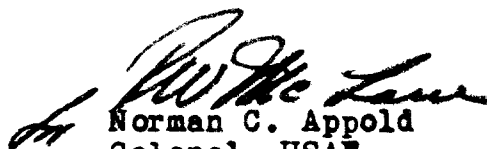
An attempt was made to produce a useful cermet solid body having as the ceramic component a material with a very low coefficient of expansion and as the metal component a metal with a melting point above the operating temperature of a gas-turbine engine.

Due to the low melting temperatures of the two ceramic materials investigated, wetting of the components was not achieved and consequently a cermet body did not result.

PUBLICATION REVIEW

The publication of this report does not constitute approval by the Air Force of the findings or the conclusions contained therein. It is published primarily for the exchange and stimulation of ideas.

FOR THE COMMANDING GENERAL:



Norman C. Appold
Colonel, USAF
Chief, Power Plant Laboratory
Aeronautics Division

INTRODUCTION

In thermal cycling tests conducted at Wright Air Development Center, nozzle diaphragm partitions (stator blades) of simulated air foil shape and dimensions, and fabricated of ceramic materials having very low coefficients of expansion, for example fused quartz, cordierite (magnesium-aluminum silicate), and "Stupalith" (lithium-aluminum silicate), showed excellent resistance to thermal shock. They were, however, very brittle and quite fragile. Fused quartz is subject to crystallization and loss of strength at operating temperatures, and both cordierite and "Stupalith" have softening and melting points so low as to provide only a narrow margin of safety between operating temperatures and the fusion temperatures of the respective materials.

Because such diaphragm partitions are neither subjected in service to the same stresses nor to stresses of the same magnitude as are rotor blades, and because the ceramic component would have a lower coefficient of expansion than alumina, it was postulated that a cermet body consisting of one or the other of the above mentioned silicates and an alloy having the lowest possible coefficient of expansion such as Kovar or Invar, might be adequate in mechanical strength, resistance to thermal shock, and resistance to oxidation, for service as diaphragm partitions.

A literature survey disclosed no data on the thermal expansion of either cordierite or "Stupalith" above 1112°F. (600°C). The fact was disclosed that Invar, Kovar (Fernico I) and Fernico II have abrupt breaks in their coefficient of expansion curves as low as 572°F. (300°C.) and in all cases below 932°F. (500°C.) These facts were taken into consideration in determining the binder metals to be investigated. While the prospect of developing a useful cermet body did not appear too promising, it was decided to first try the usual binder metals and come back to Invar and Kovar later if this appeared to be warranted. The metals or metal compounds selected were nickel, cobalt, iron, chromium, aluminum, and molybdenum disilicide. The cordierite used in the study was made in this laboratory. The "Stupalith" was fired body No. 2417 furnished through the courtesy of the Stupakoff Ceramic and Mfg. Co.

1. Materials

(a) Cordierite.

The cordierite body used as one of the ceramic components was made of 22.0% Alorco hard-calcined T-61 Al_2O_3

milled to -325 mesh, 35.0% Kamec primary kaolin, and 43.0% Sierra talc. The body was wet milled, dried and fired at 2550°F. The literature gives its coefficient of expansion as 0.53×10^{-6} from 0 to 200°C. and 1.30×10^{-6} from 200° to 600°C.

(b) Stupalith Body #2417.

The exact composition of this body is not known to us but it is essentially lithium-aluminum silicate. It was furnished as fired commercial scrap body. Its coefficient of expansion was given as 0.063×10^{-6} between 20° and 300°C.

(c) Binder Metals.

Iron. Pure iron -325 mesh supplied by Plastic Metals Inc., Johnstown, Pa.

Nickel. Annealed nickel powder, 98/99% nickel, -325 mesh. Supplied by Charles Hardy, Inc. 420 Lexington Ave, New York 17, N. Y.

Cobalt. 98% cobalt, -325 mesh. Charles Hardy, Inc.

Chromium. 99+% electrolytic chromium, -325 mesh. Charles Hardy, Inc.

Molybdenum Disilicide. Supplied by Electrometallurgical Division; Union Carbide and Carbon Corp., Cleveland, Ohio. -325 mesh powder.

2. Wetting Tests

Following our usual procedure, wetting tests were made in two ways, (1) pressed pellets of the respective metals were fired at several temperatures in flat cups of the respective ceramic components and (2) 50-50 by weight mixtures of the same compositions were thoroughly wet mixed in benzene, dried, pressed into small compacts and then sintered at several different temperatures.

3. Firing of Wetting-Test Specimens

All sintering was done in helium and over a range of temperatures to determine the temperature at which wetting might take place, also the optimum temperature at which the best physical structure would result. In some of the firings there was enough leakage of oxygen into the system to indicate whether or not the presence of oxygen might promote wetting. Because of the low melting temperatures of both ceramic components, the range of sintering temperatures had to be kept lower than normally employed for

the binder metals used. In spite of this, metal beads sweat out in many cases.

4. Results of the Wetting Tests

Neither type of wetting test gave any evidence of wetting. At the highest temperatures, fusion of the ceramic component occurred or metal beads sweat out. At lower temperatures the systems remained simply mechanical mixtures of varying degrees of hardness. Some were physically homogeneous but all were porous.

The optimum sintering temperature for the cordierite mixtures containing 50% of iron, nickel, cobalt, and chromium respectively, was found to be 2400°F. held for one hour. With 50% of molybdenum disilicide the best temperature was 2600°F. for one hour. However, nickel and cobalt tended to sweat out at all temperatures and iron tended to cause slagging.

The optimum sintering temperature for Stupalith mixtures containing 50% of iron or nickel was found to be 2200°F. held for one hour; for 50% cobalt or molybdenum disilicide, 2300°F. for one hour; and for 50% chromium, 2400°F. held for the same time. Nickel and cobalt tended to sweat out at all temperatures and iron caused a glassy slag to form.

5. Bar Specimens

All compacts of the 50-50 mixtures mentioned above were sectioned by means of a diamond saw and the structures studied. In spite of the fact that no dense structures were obtained, it was decided to make standard bar specimens which could be used for modulus of rupture, apparent porosity, resistance to oxidation, and thermal shock tests if such tests appeared to be justified. It was necessary to use Carbowax as a body lubricant. The bars were first pressed mechanically in a steel die at about 12,000 p.s.i. and repressed hydrostatically at 25,000 p.s.i.

Five bars of each composition were made and sintered in helium at the predetermined optimum temperature for varying lengths of time. Some bars were better than others as far as visual physical condition is concerned, but all were porous and weak. No cermet body has resulted which even remotely resembles a satisfactory material. In addition to the short and critical firing range of these magnesium-aluminum silicates and lithium-aluminum silicates, the basic obstacle to their successful use is their low melting point. They melt and bloat below the practical sintering and wetting temperature of the metals with which

we have sought to combine them. Any lower melting metals melt too low and have such high coefficients of expansion as to be incompatible with a ceramic component of very low expansion. We are therefore turning our attention to the metal bonding of mullite ($3\text{Al}_2\text{O}_3 \cdot 2\text{SiO}_2$) and aluminum titanate ($\text{Al}_2\text{O}_3 \cdot \text{TiO}_2$).